400 Rec'd PCT/PTO 02 JUL 1999

FORM PTO-1390 (REV. 1-98) U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE		ATTORNEY 'S DOCKET NUMBER DC277.FP99.010
TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371		U.S. APPLICATION NO. (If known, see 37 CFR 1.5) 09/341093
INTERNATIONAL APPLICATION NO. PCT/GB98/00015	INTERNATIONAL FILING DATE 05 JANUARY 1998	PRIORITY DATE CLAIMED 04 JANUARY 1997
TITLE OF INVENTION SLEEPINESS DETECTION FOR VEHICLE DRIVER OR MACHINE OPERATOR		
APPLICANT(S) FOR DO/EO/US James Anthony HORNE and Louise Ann REYNER		

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. [X] This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. [ ] This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. [X] This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. [X] A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. [X] A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   a. [X] is transmitted herewith (required only if not transmitted by the International Bureau).
   b. [ ] has been transmitted by the International Bureau.
   c. [ ] is not required, as the application was filed in the United States Receiving Office (RO/US).
6. [ ] A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. [ ] Amendments to the claims of the International Aplication under PCT Article 19 (35 U.S.C. 371(c)(3))
   a. [ ] are transmitted herewith (required only if not transmitted by the International Bureau).
   b. [ ] have been transmitted by the International Bureau.
   c. [ ] have not been made; however, the time limit for making such amendments has NOT expired.
   d. [ ] have not been made and will not be made.
8. [ ] A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371 (c)(3)).
9. [ ] An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. [ ] A translation of the annexes of the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. to 16. below concern document(s) or information included:

11. [ ] An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. [ ] An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. [X] A FIRST preliminary amendment.
    [ ] A SECOND or SUBSEQUENT preliminary amendment.
14. [ ] A substitute specification.
15. [ ] A change of power of attorney and/or address letter.
16. [X] Other items or information: International Preliminary Examination Report (PCT/IPEA/409)
    International Search Report (PCT/ISA/210)
    Patent Application Data Entry Format Sheet

80 Rec'd PCT/PTO 02 JUL 1999

U.S. APPLICATION NO. (if known, see 37 CFR 1.5) 09/341093	INTERNATIONAL APPLICATION NO. PCT/GB98/00015	ATTORNEY'S DOCKET NUMBER DC277.FP99.010

		CALCULATIONS	PTO USE ONLY
17. [X] The following fees are submitted: BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)): Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO .... $ 970.00 International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO .... $840.00 International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO .... $ International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4) .... $670.00 International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4) $96.00			
ENTER APPROPRIATE BASIC FEE AMOUNT =		$ 840	
Surcharge of $130.00 for furnishing the oath or declaration later than [ ] 20 [X] 30 months from the earliest claimed priority date (37 CFR 1.492(e)).		$ 130	

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	9 - 20 =	0	x $18.00	$	
Independent claims	1 - 3 =	0	x $78.00	$	
MULTIPLE DEPENDENT CLAIM(S) (if applicable)			+ $260.00	$	
TOTAL OF ABOVE CALCULATIONS =				$ 970	
Reduction of 1/2 for filing by small entity, if applicable. A Small Entity Statement must also be filed (Note 37 CFR 1.9, 1.27, 1.28). +				$	
SUBTOTAL =				$ 970	
Processing fee of $130.00 for furnishing the English translation later than [ ] 20 [ ] 30 months from the earliest claimed priority date (37 CFR 1.492(f)).				$	
TOTAL NATIONAL FEE =				$ 970	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). $40.00 per property +				$	
TOTAL FEES ENCLOSED =				$ 970	
				Amount to be refunded:	$
				charged:	$

a. [X] A check in the amount of $ 970. to cover the above fees is enclosed.

b. [ ] Please charge my Deposit Account No. ______ in the amount of $ ______ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. [X] The Commissioner is hereby authorized to charge any additional fees which may be required by 37 CFR 1.16 and 1.17, or credit any overpayment to Deposit Account No. 25-0120. A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137 (a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

Young & Thompson
745 South 23rd Street
2nd Floor
Arlington, VA 22202
(703) 521-2297

July 2, 1999

Benoit Castel
SIGNATURE

Benoit Castel
NAME

35,041
REGISTRATION NUMBER

Form A

VERIFIED STATEMENT CLAIMING SMALL ENTITY STATUS (37 CFR 1.9(f) & 1.27(b))--INDEPENDENT INVENTOR

Docket Number (Optional) DC277.FP99:010

Applicant or Patentee: James Anthony HORNE et al.

Serial or Patent No.: ____________

Filed or Issued: July 2, 1999

Title: SLEEPINESS DETECTION FOR VEHICLE DRIVER OR MACHINE OPERATOR

As a below named inventor, I hereby declare that I qualify as an independent inventor as defined in 37 CFR 1.9(c) for purposes of paying reduced fees to the Patent and Trademark Office described in:

- [ ] the specification filed herewith with title as listed above.
- [X] the application identified above.
- [ ] the patent identified above.

I have not assigned, granted, conveyed or licensed and am under no obligation under contract or law to assign, grant, convey or license, any rights in the invention to any person who would not qualify as an independent inventor under 37 CFR 1.9(c) if that person had made the invention, or to any concern which would not qualify as a small business concern under 37 CFR 1.9(d) or a nonprofit organization under 37 CFR 1.9(e).

Each person, concern or organization to which I have assigned, granted, conveyed, or licensed or am under an obligation under contract or law to assign, grant, convey, or license any rights in the invention is listed below:

- [ ] No such person, concern, or organization exists.
- [ ] Each such person, concern or organization is listed below.

Separate verified statements are required from each named person, concern or organization having rights to the invention averring to their status as small entities. (37 CFR 1.27)

I acknowledge the duty to file, in this application or patent, notification of any change in status resulting in loss of entitlement to small entity status prior to paying, or at the time of paying, the earliest of the issue fee or any maintenance fee due after the date on which status as a small entity is no longer appropriate. (37 CFR 1.28(b))

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application, any patent issuing thereon, or any patent to which this verified statement is directed.

James Anthony HORNE	Louise Ann REYNER	
NAME OF INVENTOR	NAME OF INVENTOR	NAME OF INVENTOR
Signature of inventor	Signature of inventor	Signature of inventor
21 Aug 99	21/8/99	
Date	Date	Date

09/341093

80Rec'd PCT/PTO 02 JUL 1999

PATENTS

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of

James Anthony HORNE et al.

Serial No. (unknown)

Filed herewith

SLEEPINESS DETECTION FOR
VEHICLE DRIVER OR MACHINE
OPERATOR

PRELIMINARY AMENDMENT

Assistant Commissioner for Patents

Washington, D.C. 20231

Sir:

Prior to the first Official Action and calculation of the filing fee, please replace Claims 1-11 as originally filed, which appear on pages 16 and 17, with Claims 1-10 as filed in the Article 34 amendment of 30 November 1998. The replacement pages containing Claims 1-10 are marked "AMENDED SHEET" and are attached hereto. Following the insertion of Claims 1-10, please amend these claims as follows:

IN THE CLAIMS:

Claim 3, line 2, change "either of the preceding claims" to --claim 1--.

Claim 4, line 2, change "any of the preceding claims" to --claim 1--.

Claim 5, line 2, change "any of the preceding claims" to --claim 1--.

Claim 6, line 2, change "any of the preceding claims" to --claim 1--.

Claim 7, line 2, change "any of the preceding claims" to --claim 1--.

Claim 8, line 2, change "any of the preceding claims" to --claim 1--.

Cancel claim 9.

Claim 10, line 3, change "any of the preceding claims" to --claim 1--.

R E M A R K S

The above changes in the claims merely place this national phase application in the same condition as it was during Chapter II of the international phase, with the multiple dependencies being removed. Following entry of this amendment by substitution of the pages, only claims 1-8 and 10 remain pending in this application.

Respectfully submitted,

YOUNG & THOMPSON

By Benoît Castel

Benoît Castel
Attorney for Applicants
Registration No. 35,041
745 South 23rd Street
Arlington, VA 22202
Telephone: 703/521-2297

July 2, 1999

09/341093

WO 98/29847 30/PRTS PCT/GB98/00015

30 Rec'd PCT/PTO 02 JUL 1999

Sleepiness Detection for Vehicle Driver or Machine Operator

This invention relates to human sleepiness, drowsiness or (lack of) alertness detection and monitoring, to provide a warning indication in relation to the capacity or fitness to drive or operate (moving) machinery.

Although its rationale is not fully understood, it is generally agreed that sleep is a powerful and vital, biological need, which - if ignored - can be more incapacitating than realised, either by a sleepy individual subject, or by those tasking the subject.

As such, the invention is particularly, but not exclusively, concerned with the (automated) recognition of sleepiness and performance-impaired fatigue in drivers of motor vehicles upon the public highway.

Professional drivers of, say, long-haul freight lorries or public transport coaches are especially vulnerable to fatigue, loss of attention and driving impairment.

With this mind, their working and active driving hours are already carefully monitored to ensure they are within prescribed limits.

Road accidents, some with no apparent external cause, have been attributed to driver fatigue.

Studies, including those by the Applicants themselves, (see the appended references), into sleep-related vehicle accidents have concluded that such accidents are largely dependent on the time of day.

Age may also be a factor - with young adults more likely to have accidents in the early morning, whereas older adults may be more vulnerable in the early afternoon.

Drivers may not recollect having fallen asleep, but may be aware of a precursory sleepy state, as normal sleep does not occur spontaneously without warning.

The present invention addresses sleepiness monitoring, to engender awareness of a state of sleepiness, in turn to prompt safe countermeasures, such as stopping driving and having a nap.

Accidents have also been found to be most frequent on monotonous roads, such as motorways and other main roads.

Indeed, as many as 20-25% of motorway accidents seem to be as a result of drivers falling asleep at the wheel.

Although certain studies concluded that it is almost impossible to fall asleep while driving without any warning whatsoever, drivers frequently persevere with their driving when they are sleepy and should stop.

Various driver monitoring devices, such as eyelid movement detectors, have been proposed to assess fatigue, but the underlying principles are not well-founded or properly understood.

Sleepiness in the context of driving is problematic, because the behavioural and psychological processes which accompany falling asleep at the wheel may not typify the characteristics of sleep onset commonly reported under test conditions and simulations by sleep laboratories.

Driving will tend to make a driver put considerable effort into remaining awake, and in doing so, the driver will exhibit different durations and sequences of psychological and behavioural events that precede sleep onset.

As underlying sleepiness may be masked by this prefacing compensatory effort, the criteria for determining whether a subject is falling asleep may be unclear.

Indeed, the Applicants have determined by practical investigation that parameters usually accepted to indicate falling asleep are actually not reliable as an index of sleepiness if the subject is driving.

For example, although in general eye blink rate has a tendency to rise with increasing sleepiness, this rate of change is confounded by the demand, variety and so stimulus content or level of a task undertaken (eg driving), there being a negative correlation between blink rate and task difficulty.

In an attempt to prevent sleep-related vehicle accidents, it is also known passively to monitor driver working times through chronological activity logs, such as tachographs. However, these provide no active warning indication.

More generally, it is also known to monitor a whole range of machine and human factors for vehicle engineering development purposes, some merely for historic data accumulation, and other unsatisfactory attempts at 'real-time' active warning.

The Applicants are not aware of any practical implementation hitherto of sleepiness detection, using relevant and proven biological factors addressing inherent body condition and capacity.

Studies and trials carried out by the Applicants have shown that there are clear discernible peaks of sleep-related vehicle accidents in the UK around 02.00-06.00 hours and 14.00-16.00 hours.

Similar time-of-day data for such accidents have been reported for the USA, Israel and Finland.

These sleep-related vehicle accident peaks are distinct from the peak times for all road traffic accidents in the UK - which are around the main commuting times of 08.00 hours and 17.00 hours.

The term 'sleepiness' is used herein to embrace essentially pre-sleep conditions, rather than sleep detection itself, since, once allowed to fall asleep, it may be too late to provide useful accident avoidance warning indication or correction.

Generally, a condition or state of sleepiness dictates

- a lessened awareness of surroundings and events;
- a reduced capacity to react appropriately; and
- an extended reaction time.

It is known from sleep research studies that the normal human body biological or physiological activity varies with the time of day, over a 24 hour, (night-day-night) cycle - in a characteristic regular pattern, identified as the circadian rhythm, biorhythm or body clock.

The human body thus has a certain pre-disposition to drowsiness or sleep at certain periods during the day - especially in early morning hours and mid-afternoon.

This is exacerbated by metabolic factors, in particular consumption of alcohol, rather than necessarily food *per se*.

According to one aspect of the invention,
a monitor taking account of circadian and sleep parameters
of an individual vehicle driver,
and/or generic or universal human physiological factors,
applicable to a whole class or category of drivers,
is integrated with 'real-time' behavioural sensing,
such as of road condition and driver control action,
including steering and acceleration,
to provide an (audio-) visual indication of sleepiness.

For safety and legislative reasons, it is not envisaged that, at least in the immediate future, an alert condition would necessarily be allowed automatically to over-ride driver control - say by progressively disabling or disengaging the vehicle accelerator.

Rather, it would remain a driver's responsibility to respond constructively to an alert issued by the system - which could log the issue of such warnings for future reference in assessing compliance.

Overall system capability could embrace recognition any or all of such factors as:

- common, if not universal, underlying patterns of sleepiness (pre-conditioning);
- exacerbating personal factors for a particular user-driver, such as recent sleep patterns especially, recent sleep deprivation and/or disruption;
- with a weighting according to other factors, such as the current time of day.

Thus background circumstances, in particular a natural alertness 'low point' - and attendant sleepiness or susceptibility to (unprompted) sleep - in the natural physiological biorhythmic or circadian cycle may pre-dispose a driver to sleepiness, exacerbated by sleep deprivation in a recent normal sleep period.

If not circadian rhythm patterns themselves, at least the ability of the body behaviour and activity to respond to the underlying pre-disposition or pre-condition, may be disturbed or frustrated by abnormal or changing shift patterns, prefaced by inadequate acclimatisation.

Thus, for example, in exercising vehicle control, aberrant driver steering behaviour, associated with degrees of driver sleepiness, could be recognised and corrected - or at least a warning issued of the need for correction (by sleep restitution).

Pragmatically, any sleepiness warning indication should be of a kind and in sufficient time to trigger corrective action.

According to another aspect of the invention,
a driver sleepiness,
alertness or fitness condition monitor
comprises
a plurality of sensory inputs,
variously and respectively related to,
vehicle motion and steering direction,
circadian or biorhythmic physiological patterns,
recent driver experiences
and pre-conditioning;
such inputs being individually weighted,
according to contributory importance,
and combined in a computational decision algorithm or model,
to provide a warning indication of sleepiness.

Some embodiments of the invention can take into account actual, or real-time, vehicle driving actions, such as use of steering and accelerator, and integrate them with inherent biological factors and current personal data, for example recent sleep pattern, age, sex, recent alcohol consumption (within the legal limit), reliant upon input by a driver being monitored.

Steering action or performance is best assessed when driving along a relatively straight road, such as a trunk, arterial road or motorway, when steering inputs of an alert driver are characterised by frequent, minor correction.

In this regard, certain roads have characteristics, such as prolonged 'straightness' and monotonous contouring or landscaping, which are known to engender or accentuate driver sleepiness.

It is envisaged that embodiments of the steering detector would also be able to recognise when a vehicle is on such (typically straighter) roads.

Some means, either automatically through a steering sensor, or even from manual input by the driver, is desirable to recognised motorway as opposed to, say, town driving conditions, where large steering movements obscure steering irregularities or inconsistencies.

Indeed, the very act of frequent steering tends to contribute to, or stimulate, wakefulness. Yet a countervailing tendency to inconsistent or erratic steering input may prevail, which when recognised can signal an underlying sleepiness tendency.

In practice, having recognised the onset of journeys on roads with an enhanced sleepiness risk factor, journey times on such roads beyond a prescribed threshold - say 10 minutes - could trigger a steering action detection mode, with a comparative test against a steering characteristic algorithm, to detect sleepy-type driving, and issue a warning indication in good time for corrective action.

As another vehicle control condition indicator, accelerator action, such as steadiness of depression, is differently assessed for cars than lorries, because of the different spring return action.

Implementation of semi-automated controls, such as cruise-controls, with constant speed setting capabilities, could be disabled temporarily for sleepiness monitoring.

In assessing driver responses to pre-programmed device interrogation, reliance is necessarily placed upon the good intentions, frankness and honesty of the individual.

A practical device would embody a visual and/or auditory display to relay warning messages and instructions to and responses from the user.

Similarly, interfaces for vehicle condition sensors, such as those monitoring steering and accelerator use, could be incorporated.

Furthermore, input (push-button) switches for driver responses could also feature - conveniently adjacent to the visual display.

Input effort would be minimal to encourage participation, and questions would be straightforward and direct, to encourage explicit answers.

Visual display reinforcement messages could be combined with the auditory output.

Ancillary factors, such as driver age and sex, could also be input.

An interface with a global positioning receiver and map database could also be envisaged, so that the sleepiness indicator could register automatically roads with particular characteristics, including a poor accident record, and adjust the monitoring criteria and output warning display accordingly.

The device could be, say, dashboard or steering wheel mounted, for accessibility and readability to the driver.

Ambient external light conditions could be sensed by a photocell. Attention could thus be paid at night to road lighting conditions.

Vehicle driving cab temperature could have a profound effect upon sleepiness, and again could be monitored by a localised transducer at the driver station.

The device could categorise sleepiness to an arbitrary scale. Thus, for example, the following condition levels could be allocated:

- ALERT
- A LITTLE SLEEPY
- NOTICEABLY SLEEPY
- DIFFICULTY IN STAYING AWAKE
- FIGHTING SLEEP
- WILL FALL ASLEEP

Personal questions could include:

- QUANTITY OF SLEEP IN THE LAST 24 HOURS
- QUALITY OF THAT SLEEP IN THE LAST 24 HOURS

Road conditions could include:

- MOTORWAY
- MONOTONOUS
- TOWN

Night-time with no street lights could be given a blanket impairment rating or loading.

Assumptions are initially made of no alcohol consumption whatsoever (ie legal limits disregarded).

A circadian rhythm model allows a likelihood of falling asleep, or a sleep propensity, categorised between levels 1 and 4 - where 4 represents very likely and 1 represents unlikely.

The lowest likelihood of sleepiness occurs from mid morning to early afternoon.

Thereafter a mid afternoon lull, or rise in likelihood of sleepiness to 3 is followed by another trough of 1 in early evening, rising stepwise towards late night, through midnight and into the early hours of the morning.

There now follows a description of some particular embodiments of the invention, by way of example only, with reference to the accompanying diagrammatic and schematic drawings, in which:

Figure 1 shows the circuit layout of principal elements in a sleepiness monitor for a road vehicle driver;

Figure 2 show an installation variant for the indicator and control unit of the sleepiness monitor shown in Figure 1;

Figure 3 shows a graphical plot of varying susceptibility to sleepiness over a 24 hour period, reflecting human body circadian rhythm patterns;

Figures 4 and 5, 6 and 7, 8 and 9 show paired personal performance graphs, reflecting steering wheel inputs for three individual drivers, each pair representing comparative alert and sleepy (simulated) driving conditions;

Figure 10 shows principal elements of a driver monitor system, with an integrated multi-mode sensing module;

Figure 11 shows a sensing arrangement for motion and steering, in relation to respective reference or datum axes, for the multi-mode sensing module of Figures 10 and 12;

Figure 12 shows a the multi-mode sensor of Figure 10 in more detail;

Figures 13A through 13D show a variant housing for the multi-mode sensor of Figures 10 and 12;

Figures 14A and 14B show steering wheel dynamic sensing geometry;

Figures 15A through 15D show steering wheel movement and attendant correction;

Figures 16A and 16B show vehicle acceleration and correction;

Figure 17 shows periodic variation of sleepiness/alertness and attendant warning threshold levels;

Figure 18 shows the sub-division of system operational time cycles;

Figure 19 shows system data storage or accumulation for computation;

Figures 20/2.2 through 20/5.5 variously represent system data and computational factors and attendant software flow charts for implementing the device of Figures 1 through 19; and

Figure 21 shows a circuit diagram of a particular multi-mode sensor, with a magnetic-inductive flux coupling sensing of rate of change of steering wheel movement.

Referring to the drawings, a sleepiness monitor 10 is integrated within a housing 11, configured for ease of in-vehicle installation, for example as a dashboard mounting, or, as depicted in Figure 2, mounted upon a steering wheel 12 itself.

In a preferred variant, the monitor 10 would be self-contained, with an internal battery

power supply and all the necessary sensors fitted internally, to allow the device to be personal to a driver and moved with the driver from one vehicle to another.

An interface 19, for example a multi-way proprietary plug-and-socket connector, is provided in the housing, to allow interconnection with an additional external vehicle battery power supply and various sensors monitoring certain vehicle conditions and attendant driver control action.

Thus a steering wheel movement sensor 13 monitors steering inputs from a driver (not shown) to steering wheel 12.

The sensor 13 could be located within the steering wheel 12 and column assembly.

More sophisticated integrated multi-channel, remote sensing is described later in relation to Figures 11 and 12.

Similarly, an accelerator movement sensor 15 monitors driver inputs to an accelerator pedal 14.

Alternatively, and again in a more sophisticated sensor variant, a dynamic accelerometer could be employed, as in Figures 11 and 12.

The sensor 15 could be an accelerometer located within the housing 11 in a self-contained variant. Care is taken to obviate the adverse effects of vehicle vibration upon dynamic sensory measurements.

Albeit, somewhat less conveniently, vehicle motion and acceleration could be recognised through a transmission drive shaft sensor 27, coupled to a vehicle road wheel 26 or by interfacing with existing sensors or control processors for other purposes, such as engine and transmission management.

The trend to multiplex vehicle electrical supply systems, relaying data between vehicle operational modules, may facilitate such interconnection.

More sophisticated sensors, with an ability for remote self-contained condition sensing, data accumulation and data transfer, data down-loading or data up-loading may be employed.

Thus, for example, a steering wheel movement sensor module, a the version of Figure 21, may rely upon a wireless or contact-free linkage - such as magnetic flux coupling between magnetic elements on the wheel or shaft and an adjacent static inductive or capacitative transducer to register rate of change of wheel movement (as opposed to, say an average RMS computation of Figures 15A and 15B).

Such remote sensing and data linkage obviates the need for major vehicle wiring harness alternation or supplement.

Overall, the device could have an internal memory of speed and steering wheel

movements and so the basis of a 'performance history' of driver actions as a basis for decision upon issuing warning indication.

The interface 19 would enable data to be down-loaded onto a PC via, say, the PC parallel port or over a radio or infra-red 'wireless' link.

A further photocell sensor 29 monitors ambient light conditions from the driving position and is calibrated to assess both day-night transitions and the presence or absence of street lighting at night.

In the variants of Figures 10, 12 and 13A through 13D, multi-mode or multiple (independent) factor sensing is integrated within a common so-called 'steering wheel adaptor' module 33.

Reverting to the unit 10 of Figures 1 and 2, the housing 11 incorporates a visual display panel or screen 18, for relaying instructions and warning indications to the user.

A touch-sensitive inter-actional screen could be deployed.

Manual or automated adjustment for screen contrast according to ambient light conditions could be embodied.

The variants of Figures 10, 12 and 13A through 13D allow for a simpler devolved display of certain operating criteria, by multiple LED's on a multi-mode sensor module 33.

A loudspeaker 21 can relay reinforcement sound messages, for an integrated audio-visual driver interaction.

Also to that end, in a more sophisticated variant - possibly merely as an ongoing research and development tool, a microphone 23 might be used to record and interpret driver responses, possibly using speech recognition software.

Alternatively, interactive driver interrogation and response can be implemented a series of push button switches 16 arrayed alongside the screen 18, for the input of individual driver responses to preliminary questions displayed upon the screen 18.

Thus, for example, non-contentious factors, such as driver age and sex may be accounted for, together with more subjective review of recent sleep history.

Questions would be phrased concisely and unequivocally, for ease and immediacy of comprehension and certainty or authenticity of response.

Thus, for example, on the pivotal contributory factor of driver's recent sleep, the question:

'How much sleep have you had in the last 24 hours'

could be juxtaposed with a multiple choice on screen answer menu, such as:

CHOICE OF ONE ANSWER ...

LITTLE OR NONE ... [GENERATING A WEIGHTING SCORE OF 2]
LESS THAN NORMAL ... [SCORE 1]
ABOUT THE SAME AS NORMAL, UNDISTURBED ... [SCORE 0]
ABOUT THE SAME AS NORMAL, BUT DISTURBED ... [SCORE 1]

Other contributory factors include road conditions and vehicle cabin temperature.

Road conditions would be assessed through the steering sensor 13, and through an initial input question upon road conditions.

Thus, a dull, monotonous road would justify a weighting of plus 1 to all the circadian scores.

On the other hand, town driving, promoting greater alertness from external stimuli, would merit a score of minus 1.

Vehicle cabin temperature is taken into account, primarily to register excessively high temperatures which might induce sleepiness.

Driver cab temperatures could be monitored with a temperature sensor probe 31 (located away from any heater output vents).

Thus, for example, a threshold of some 25 degrees C might be set, with temperatures in excess of this level triggering a score of plus 0.5.

In normal operating mode, the monitor relies upon the working assumption that the driver has had little or no recent or material alcohol consumption.

The physiological circadian rhythm 'template' or reference model pre-loaded into the monitor memory is adjusted with the weighting scores indicated.

If the cumulative score is equal to or greater than 3, the steering sensor is actively engaged and checked to determine the road conditions.

The sleepiness scale values, reflected in the unweighted graph of Figure 3, can broadly be categorised as:

- ALERT
- NEITHER ALERT NOR SLEEPY
- A LITTLE SLEEPY
- NOTICEABLY SLEEPY
- DIFFICULTY IN STAYING AWAKE
- FIGHTING SLEEP
- WILL FALL ASLEEP

An internal memory module may store data from the various remote sensors 13, 15, 27, 29, 31 - together with models or algorithms of human body circadian rhythms and weighting factors to be applied to individual sensory inputs.

An internal microprocessor is programmed to perform calculations according to driver and sensory inputs and to provide an appropriate (audio-)visual warning indication of sleepiness through the display screen 18.

Figure 2 shows a steering-wheel mounted variant, in which the housing 11 sits between lower radial spokes 17 on the underside of steering wheel 12 - in a prominent viewing position for the driver, but not obstructing the existing instrumentation, in particular speedometer, nor any air bag fitted.

Ambient temperature and lighting could also be assessed from this steering wheel vantage point.

This location also facilitates registering of steering wheel movement. With an internal accelerometer and battery, external connections could be obviated.

Whilst a motor vehicle orientated monitor has been disclosed in the foregoing example, the operating principles are more widely applicable to moving machine-operator environments, as diverse as cranes, construction site excavators and drilling rigs - possibly subject to further research and development.

Figures 4 through 9 show the respective steering 'performances' of three individual subjects, designated by references S1, S2 and S3, under alert and sleepy (simulated) driving conditions.

Each graph comprises two associated plots, representing steering wheel movement in different ways.

Thus, one plot directly expresses deviations of steering wheel position from a straight-ahead reference position - allotted a 'zero' value.

This plot depicts the number of times a steering wheel is turned in either direction, over a given time period - allowing for a +/- 3% 'wobble' factor as a 'dead' or neutral band about the reference position.

The other plot is an averaged value of steering wheel movement amplitude (ie the extent of movement from the reference position) - using the RMS (root mean squared) of the actual movements.

Generally, the graphs reflect a characteristic steering performance or behaviour.

In particular, as a person becomes sleepy, zero crossings are reduced in frequency, whereas RMS amplitudes increase and/or become more variable.

Thus, Figure 4 reflects steering behaviour of an alert subject S1.

Collectively, the 'zero-crossing' and 'RMS' plots for alert subject S1 reflect a generally continual and consistent steering correction.

In contrast, the steering behaviour of a sleepy subject S1, reflected in Figure 5, exhibits less frequent, erratic, exaggerated or excessive steering movement.

Figure 6 reflects steering behaviour for another alert subject S2, whilst Figure 7 shows the corresponding readings when the same subject was sleepy.

Figure 8 reflects steering behaviour of yet another alert subject S3 and Figure 9 that of that subject S3 when sleepy.

Each pair of graphs shows corresponding marked differences in steering behaviour between an alert and sleepy driver.

This characteristic difference validates the use of actual or real-time dynamic steering behaviour to monitor driver sleepiness.

In a practical system, using steering wheel movement to identify sleepiness, on the basis of such findings, it is preferred that, <u>before</u> presenting a sleepiness warning indication, at least two of the following three sleep categorising conditions of steering behaviour are present, namely:

- Fewer zero crossings;
- RMS amplitude high;
- RMS more variable.

RMS averaging may be superceded by other sensing techniques, such as that of the magnetic flux-coupled, inductive sensor of Figure 21, which can register more directly rate of change of steering wheel movement.

Turning to refinement of practical implementation, Figure 10 shows a block schematic overall circuit layout or principal elements.

More specifically, the various sensing modes - including vehicle motion (linear acceleration), steering wheel angle, ambient light, temperature, are combined with an audio sounder and mark button in an integrated so-called 'steering wheel adaptor' module 33.

The sensor module 33 is connected through a cable way to an electronic interface 32, which in turn is configured for connection to a personal computer parallel port 39 through a cable link and a mains charger unit 37.

The orientation of the sensor module 33 in relation to reference axes for acceleration and steering wheel angular position are represented in Figures 11 and 12.

Angular sensing could be, say, through a variable magnetic flux coupling between magnets set on the steering wheel or column and on adjacent static mounts.

Figures 13A through 13D show a master sensor unit 33 with a simplified LED warning indicator array. The detailed circuitry is shown in Figure 21.

Essentially, the steering sensor measures a change in inductance through an array of some three inductors L1, L2 and L3 through magnetic flux coupling changes caused by movement in relation to the magnetic field of a small magnet 'M' static-mounted upon the steering column - at a convenient, unobtrusive location.

The inductors L1, L2 and L3 are energised by a 32kHz square wave generated by a local processor clock.

Induced voltage is rectified, smoothed, sampled and measured by the local processor some 16 times per second.

The processor analyses the results digitally to determine the extent of steering wheel movement.

Calibration of the minimum and maximum voltages across each inductor as the magnetic field of the static magnet sweeps across them when the steering wheel is fully turned is undertaken by the local processor, so the mounting location of the static magnet is not overly critical.

Such inductive sensing is unaffected by road vibration, since both static magnet and inductors are subject to the same vibration and any effect cancelled out.

The local processor feeds sensor data to an executive processor loaded with sleepiness detector algorithms, base upon such factors as circadian rhythm of sleepiness, timing and duration of sleep and ambient light, and which presents an overall indication of driver sleepiness level.

The arrangement is capable of registering and measuring very small angular movements, such as might be encountered in corrective steering action at speed.

Figures 14A through 15D relate to wheel movement sensing by a more indirect computational technique, involving RMS averging, compared with the direct rate of change capability of magnetic flux-coupled inductive sensing of the Figure 21 circuitry.

Figures 14A and 14B represent dynamic steering wheel movement sensing.

Figures 15A and 15B represent respectively 'raw' and adjusted wheel movements over time.

Figure 15C represents a 'zero crossings' count, derived from the adjusted plot of Figure 15B.

Figure 15D depicts the 'dead band' range of wheel movement allowed.

Figures 16A and 16B respectively, represent 'raw' and corrected plots of vehicle

acceleration over time - allowing computation of an RMS average acceleration.

Figure 17 depicts a characteristic circadian sleepiness rhythm or pattern, with a three-tiered sleepiness warning threshold levels.

Figure 18 represents a breakdown of system activity over (T = 60 second) operational clock cycles - with a division between monitoring the various sensors over 50 seconds and 10 seconds process time allocation for parameter calculation, test and warning issue, display screen update, sensor data storage and storage of calculated parameters.

Figure 19 represents data storage array allocation, for monitoring and learning of factors such as vehicle acceleration and wheel movement.

Hardware considerations aside, an operational software protocol would involve a schema of factors, such as represented in the listings Figures 20/2.1 through 20/5.5, which are generally self-explanatory and will not otherwise be discussed.

Component List

10	(sleepiness) monitor
11	housing
12	steering wheel
13	steering position/movement sensor
14	accelerator pedal
15	accelerator position/movement sensor
16	push-button switch
17	steering wheel spokes
18	display panel/screen
19	interface connector
21	loudspeaker
23	microphone
26	road wheel
27	(drive) shaft sensor
29	photocell sensor
31	temperature probe
33	multi-mode sensor
32	electronic interface
37	mains charger
39	parallel data port

Literature References

- J. Sleep Research 1994 vol 3 p195; 'Accidents & Sleepiness': consensus of Stockholm International Conference on work hours, sleepiness and accidents.

- J. Sleep Research 1995 suppl. 2 p23-29; 'Driver Sleepiness': J.A. Horne & L.A. Reyner
- British Medical Journal 4 March 195 vol 310 p565-567; 'Sleep related vehicle accidents': J.A. Horne & L.A. Reyner
- Int J Legal Med 1998; 'Falling asleep whilst driving: are drivers aware of prior sleepiness?: L.A. Reyner & J.A. Horne

Art. 34 Amd'14.

Amended Claims

PCT/GB00/00015
Horne et al
DC277.!P88.040

1.

A sleepiness monitor (10)
for a vehicle driver or machine operator,
comprising a sensor (13),
for registering a vehicle or machine condition factor,
and attendant control action,
an input for personal condition history,
a memory, for storing
a physiological reference model,
of circadian rhythm pattern,
and an operating model or algorithm,
for determining driver condition or vehicle action,
and computational means,
for weighting the operating model
according to registered condition, history or action,
and providing a warning indication (18)
of driver or operator sleepiness.

2.

A sleepiness monitor,
as claimed in Claim 1,
including a sensor,
for vehicle steering wheel movement,
and attendant directional control.

3.

A sleepiness monitor,
as claimed in either of the preceding claims,
including means for registering steering wheel movement,
about a reference position,
the computational means determining
the character of the route being driven
and the steering behaviour in relation to that route,
allowing account to be taken
of the frequency and amplitude of correction ,
about a straight-ahead steering position.

4.

A sleepiness monitor,
as claimed in any of the preceding claims,
including a sensor for vehicle acceleration and/or speed.

AMENDED SHEET

Art-34 Amdt

5.

A sleepiness monitor,
as claimed in any of the preceding claims,
including a temperature sensor,
for a driver or operator environment.

6.

A sleepiness monitor,
as claimed in any of the preceding claims,
including a sensor for ambient light conditions.

7.

A sleepiness monitor,
as claimed in any of the preceding claims,
including provision for driver or operator input,
of personal condition factors,
taken into account by the computational means,
in weighting the operating model or algorithm,
and adjusting a threshold of warning indication accordingly.

8.

A sleepiness monitor,
as claimed in any of the preceding claims,
including provision for driver or operator input,
of personal condition factors,
including recent sleep history
and/or alcohol consumption,
taken into account
by the computational means,
in weighting the operating model or algorithm,
and adjusting a threshold of warning indication accordingly.

9.

A sleepiness monitor,
substantially as hereinbefore described
with reference to,and as shown in,
the accompanying drawings.

10.

A vehicle or machine,
incorporating a sleepiness monitor,
as claimed in any of the preceding claims.

AMENDED SHEET

WO 98/29847

09/341093
PCT/GB98/00015

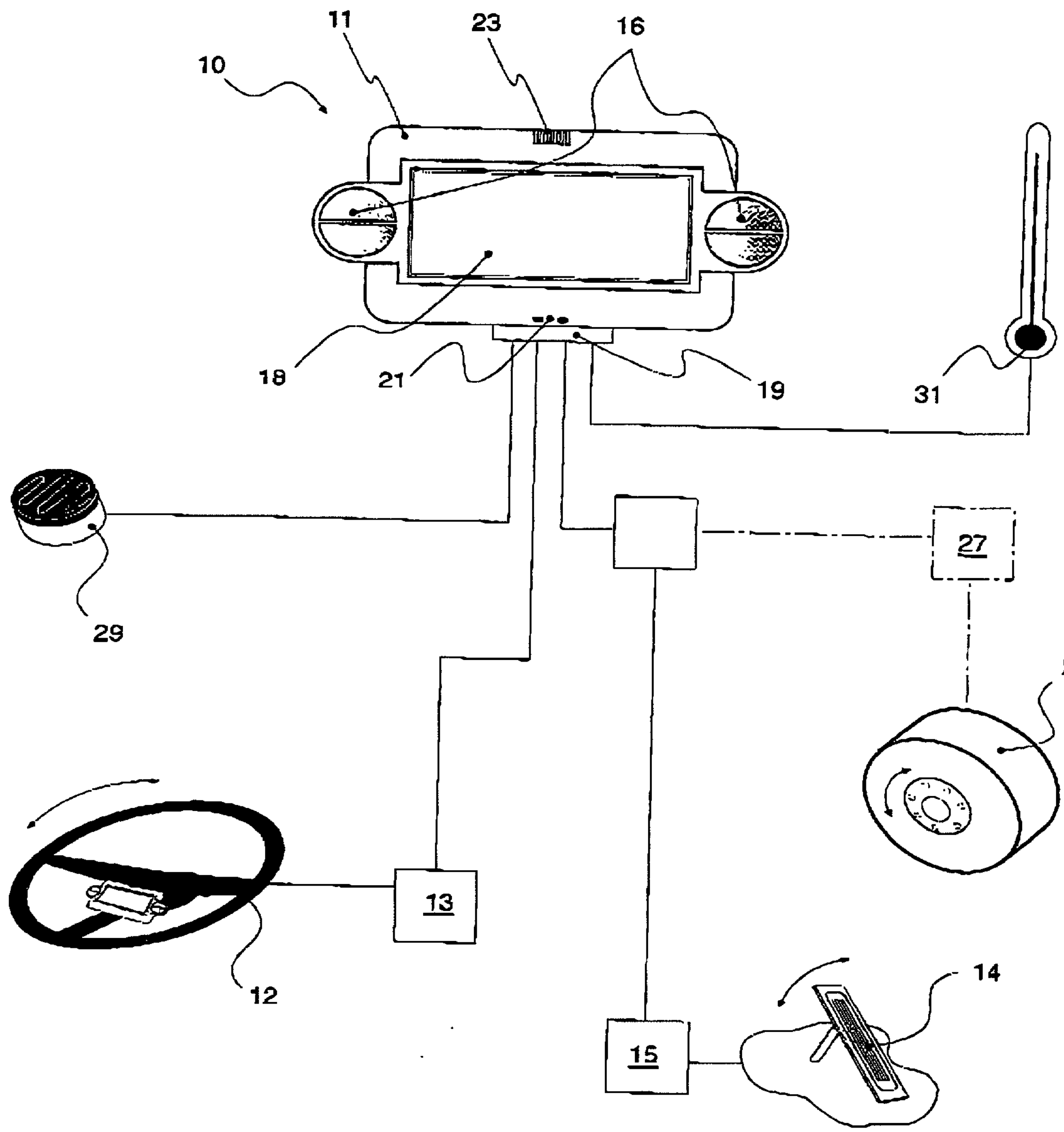


Figure 1

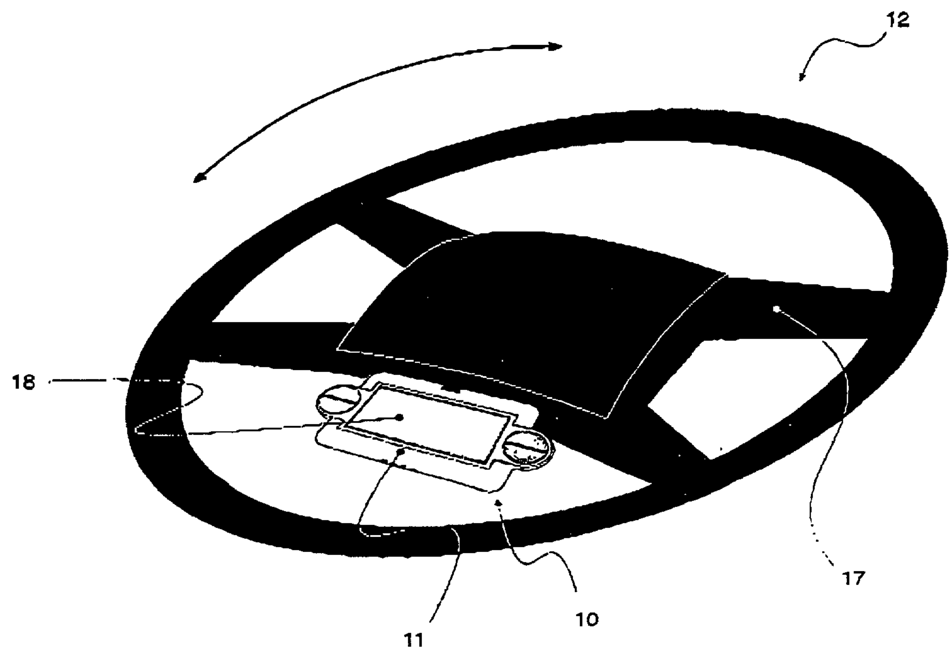


Figure 2

09/341093

LIKELIHOOD OF FALLING ASLEEP 1= unlikely, 2= possibly, 3= likely, 4= very likely, 5= certain

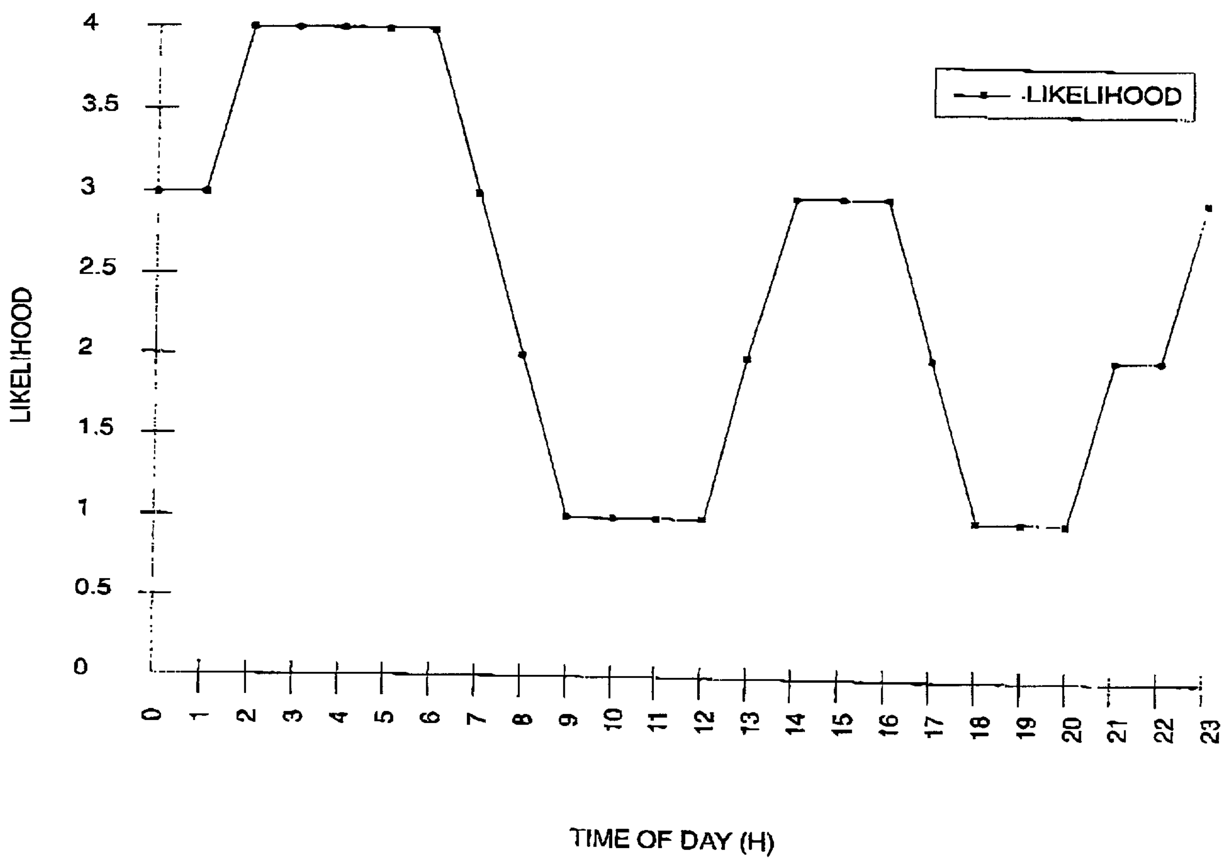


Figure 3

Figure 4

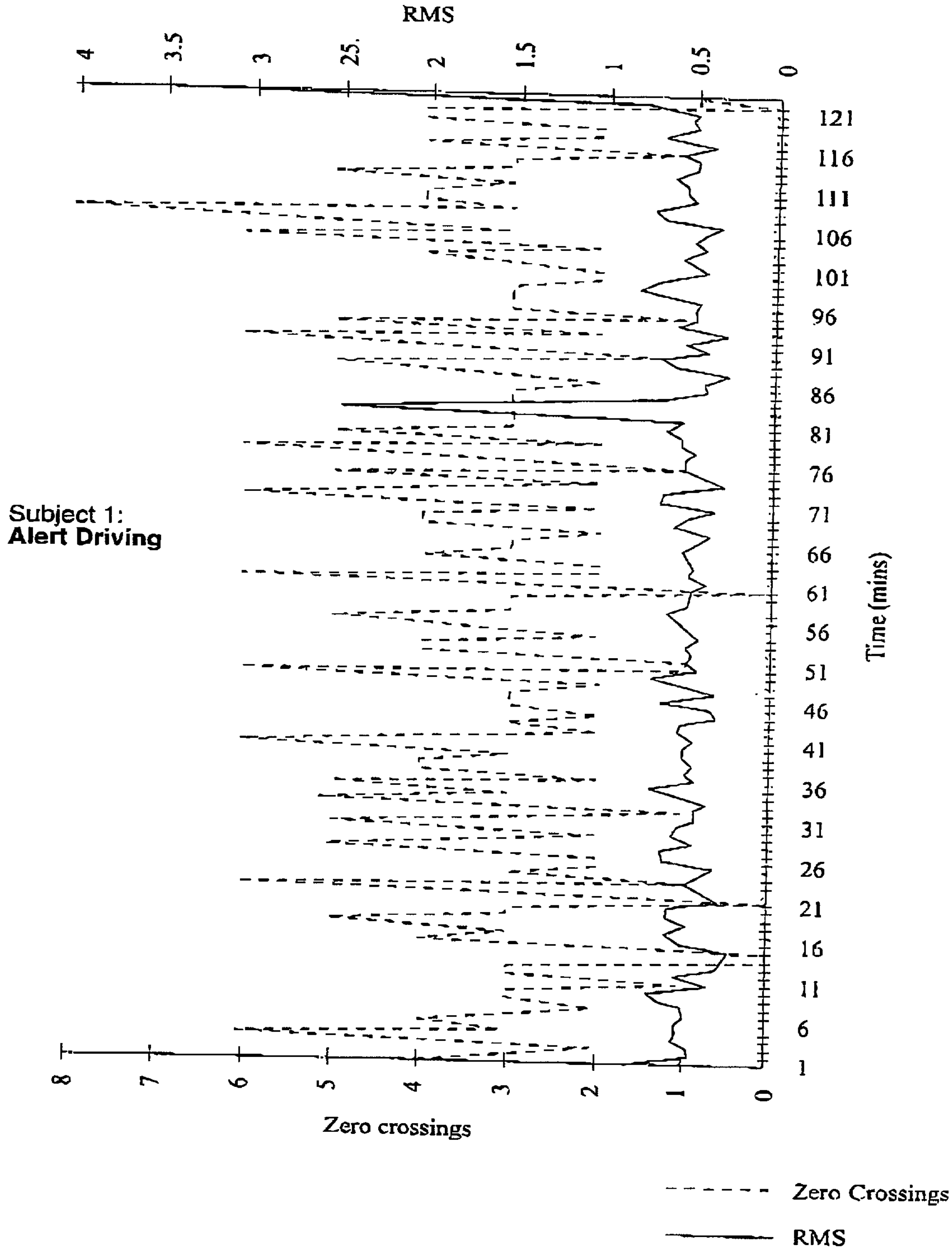

RMS
Subject 1:
Alert Driving
Time (mins)
Zero crossings
Zero Crossings
RMS

Figure 5

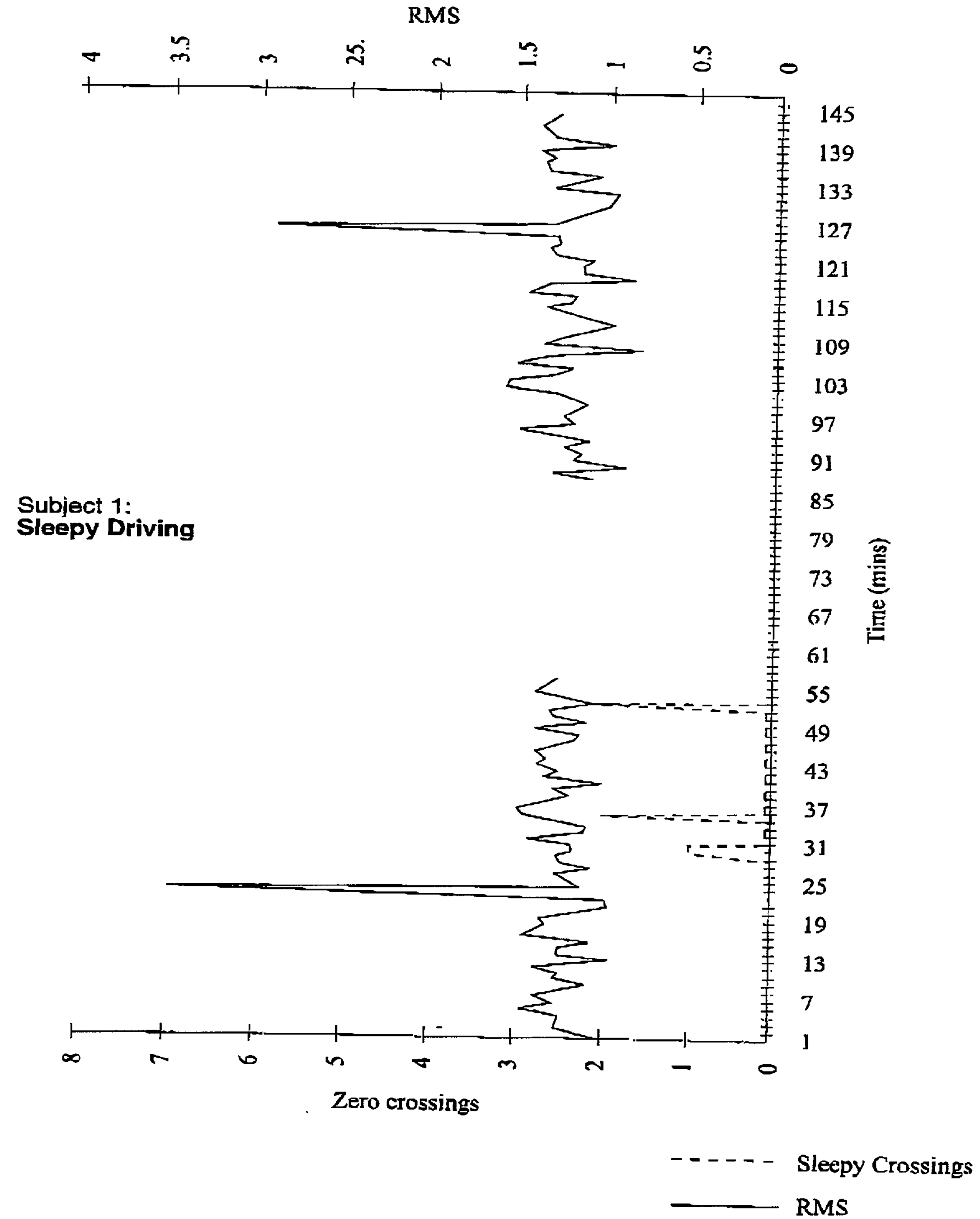

RMS
Subject 1:
Sleepy Driving
Time (mins)
Zero crossings
Sleepy Crossings
RMS

Figure 6

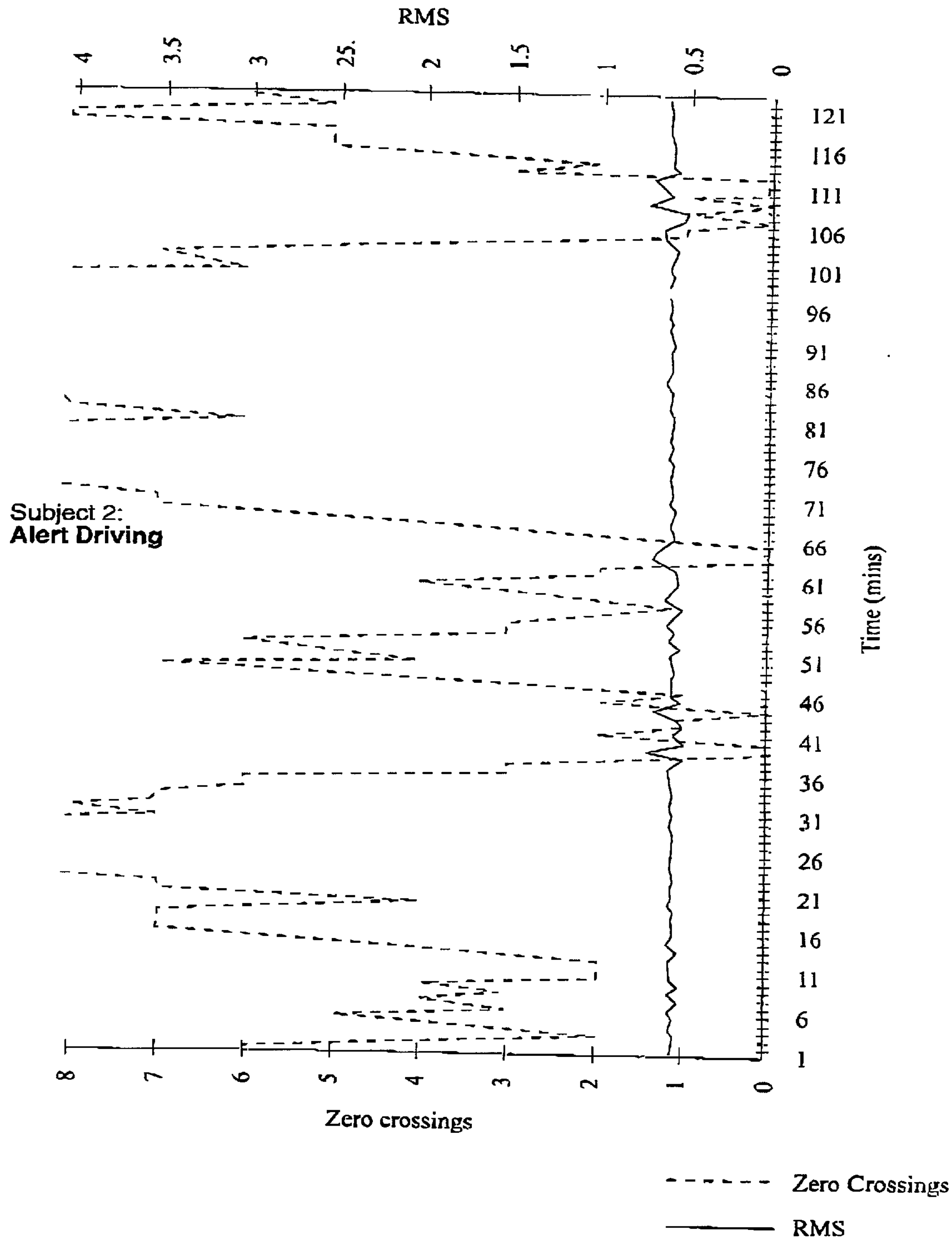
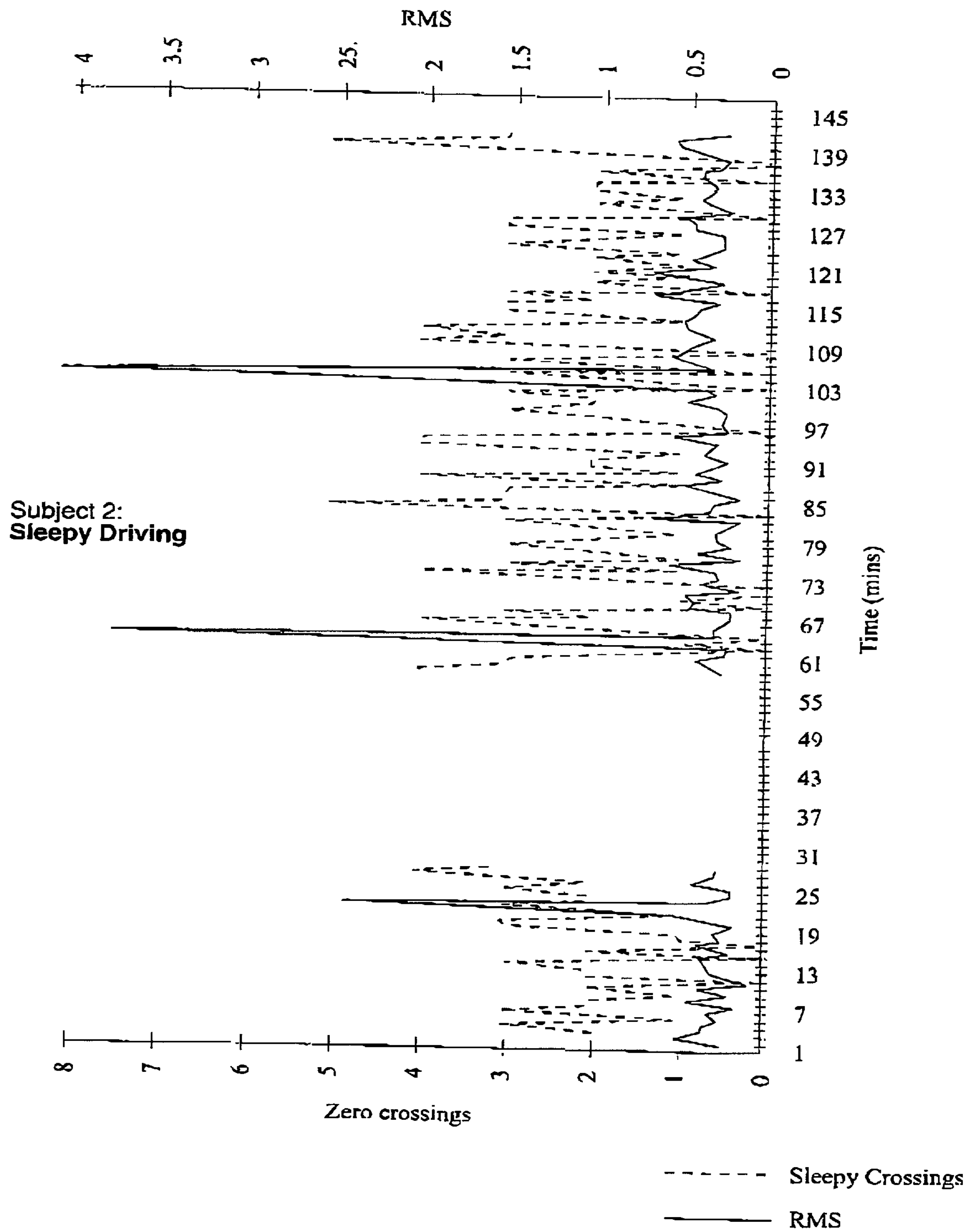

RMS
Time (mins)
Zero crossings
Subject 2:
Alert Driving
Zero Crossings
RMS

Figure 7


RMS
4
3.5
3
25.
2
1.5
1
0.5
0
Subject 2:
Sleepy Driving
145
139
133
127
121
115
109
103
97
91
85
79
73
67
61
55
49
43
37
31
25
19
13
7
1
Time (mins)
8
7
6
5
4
3
2
1
0
Zero crossings
Sleepy Crossings
RMS

09/341093

WO 98/29847 PCT/GB98/00015

Figure 8

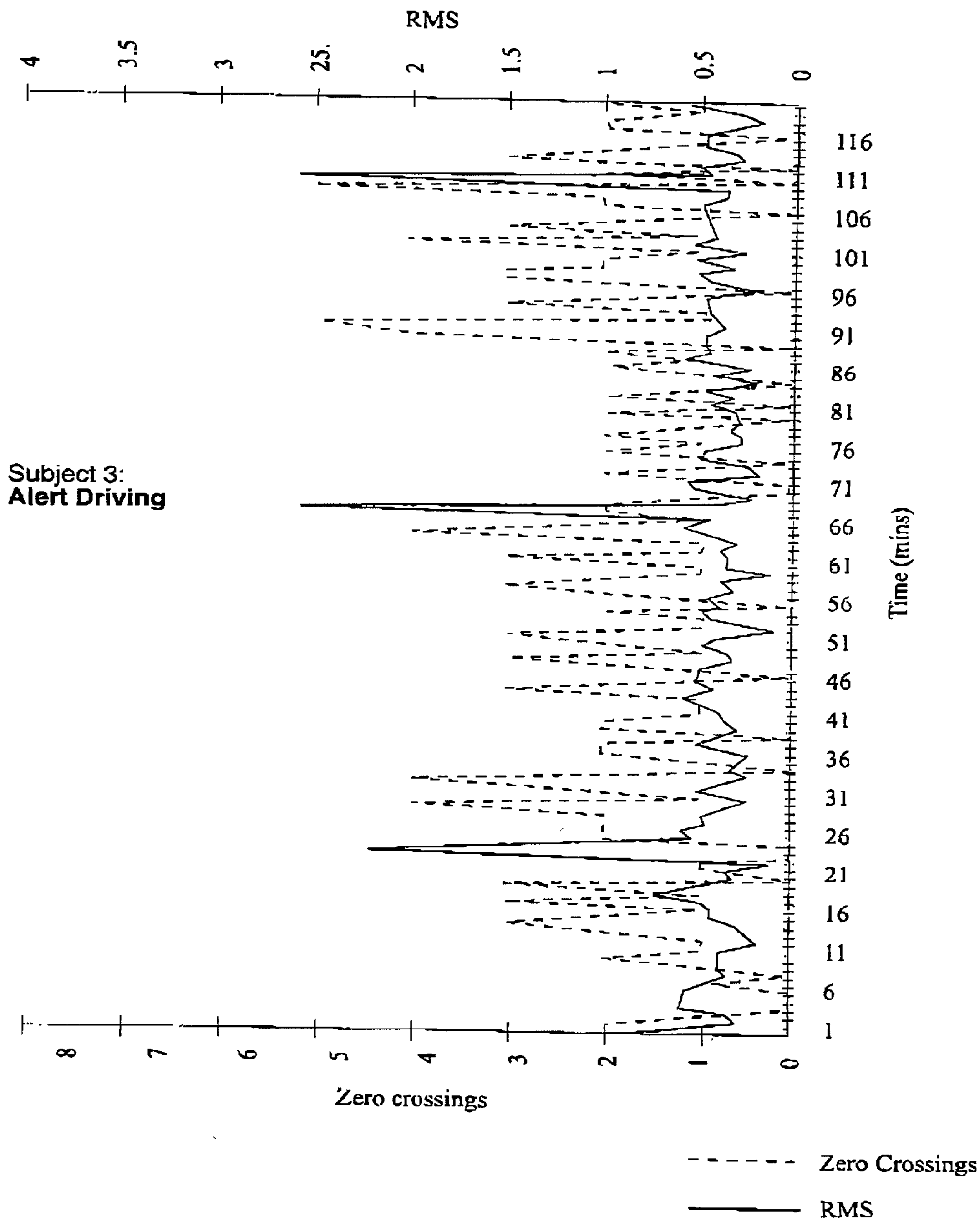


Figure 9

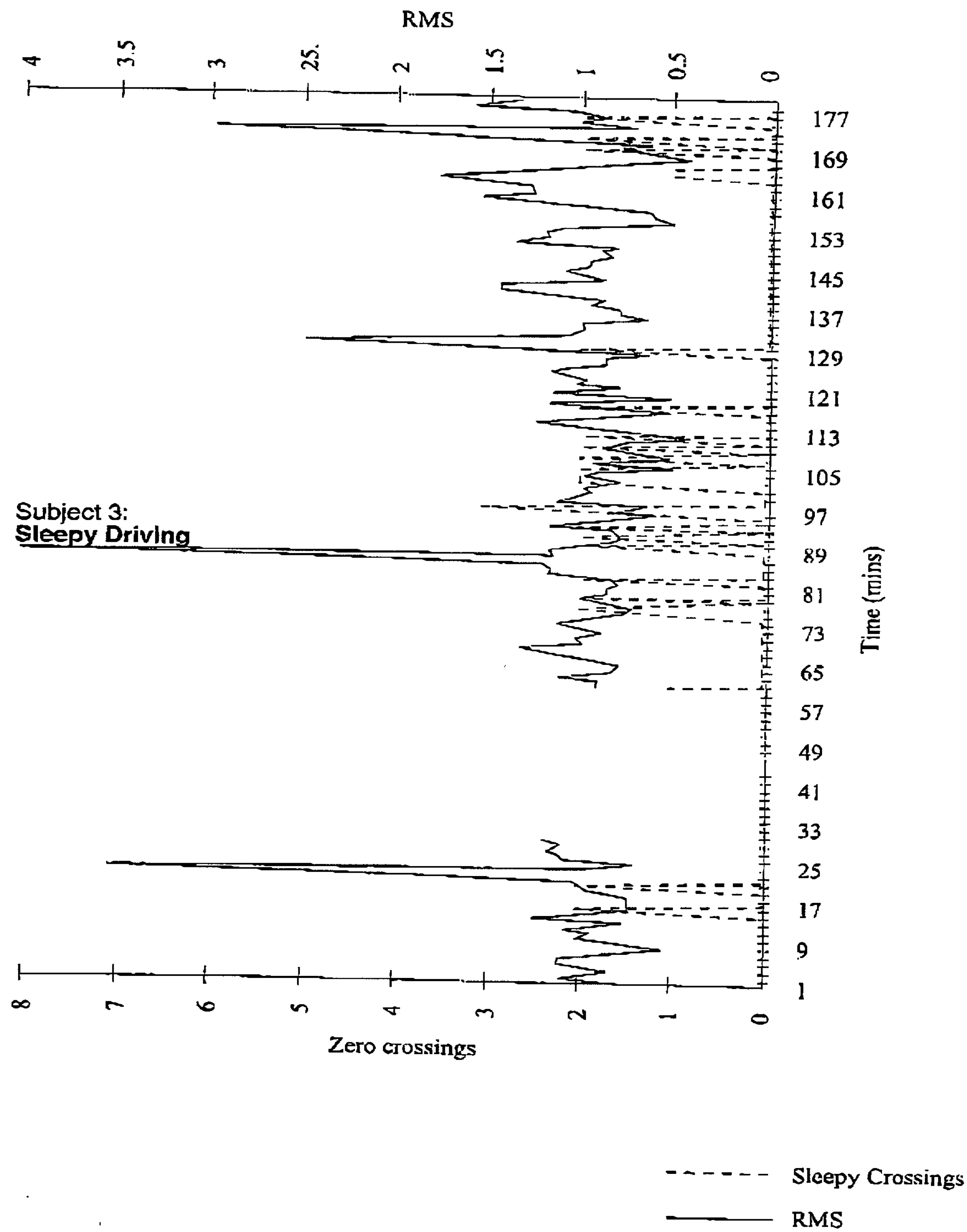

RMS
4
3.5
3
25.
2
1.5
1
0.5
0
177
169
161
153
145
137
129
121
113
105
97
89
81
73
65
57
49
41
33
25
17
9
1
Time (mins)
Subject 3:
Sleepy Driving
8
7
6
5
4
3
2
1
0
Zero crossings
Sleepy Crossings
RMS

Table 1

Acc # 1-Vehicle Motion
Acc # 2-Wheel Angle
Light Sensor - Ambient
Temp Sensor - Ambient
Sounder
Mark Button

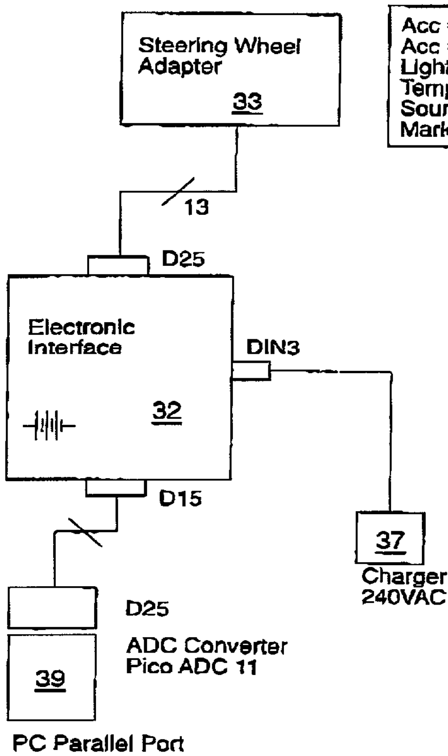


Figure 10

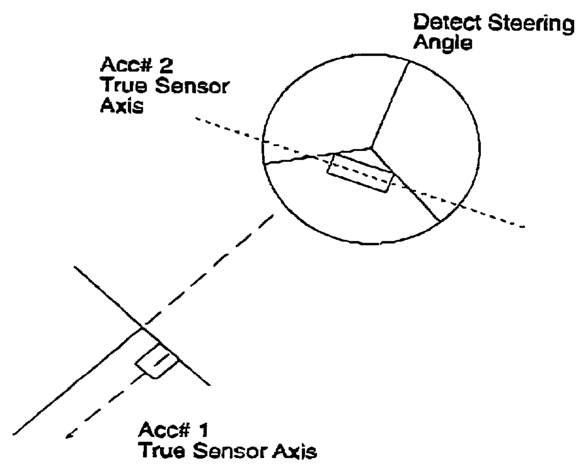


Figure 11

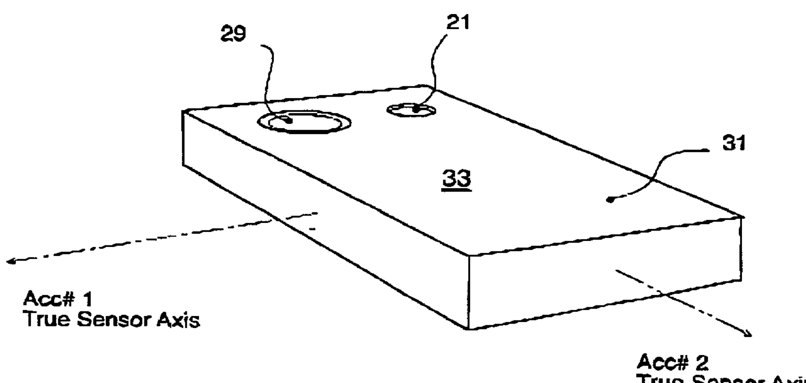


Figure 12

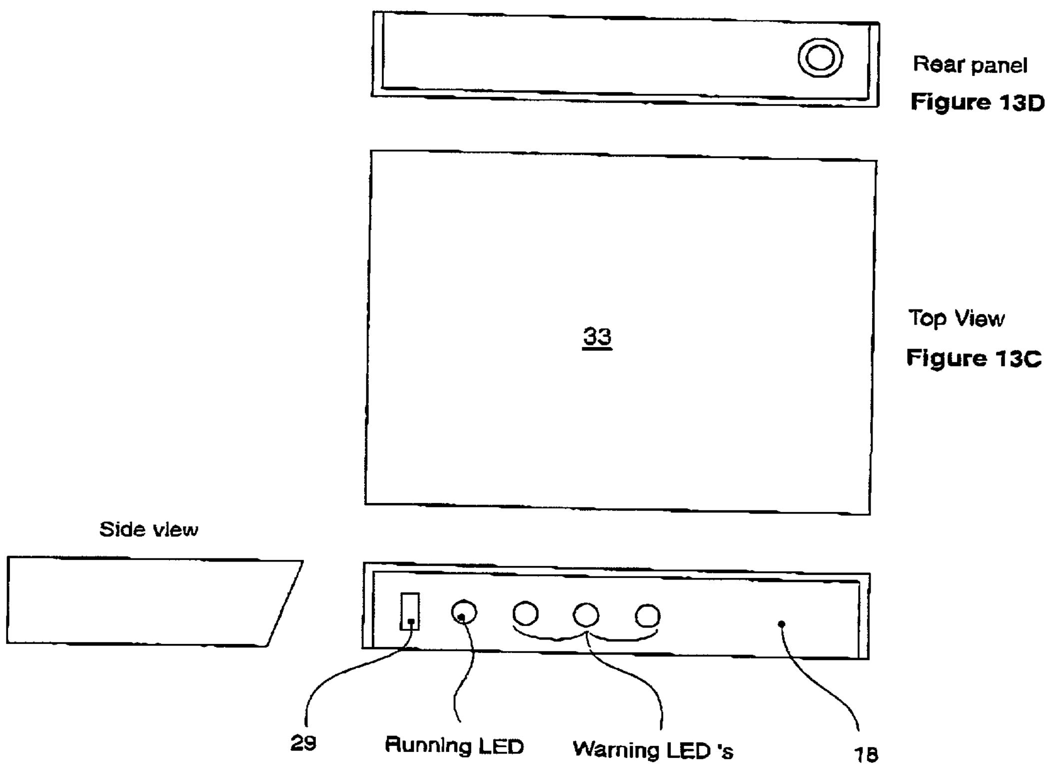


Figure 13B

Figure 13A

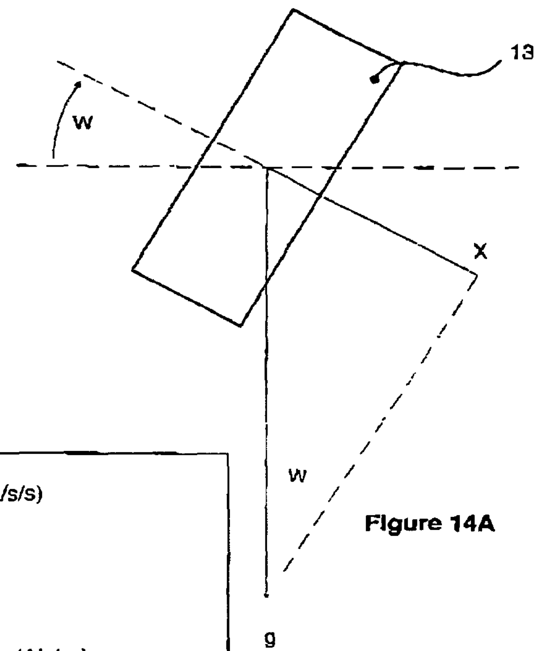


Figure 14A

Table 2

W - Wheel Rotation Angle
X - Measured component of g in sensor axis (m/s/s)
K wheel - Sensor scaling factor (mm/s/s/bit)
g - Gravity 9.81 m/s/s
g - Gravity Vector Component in wheel Plane

Sin W = X / g

X = k wheel / 1000 x (Ch(1)-ZeroWheel) x 1/Cos(Alpha)

Sin W = k wheel / (1000 x g)x(Ch(1)-ZeroWheel)x(1/Cos(Alpha)

W + ArcSin [Kwheel /(1000 x g)x(Ch(1)-ZeroWheel)x 1/Cos(Alpha)]

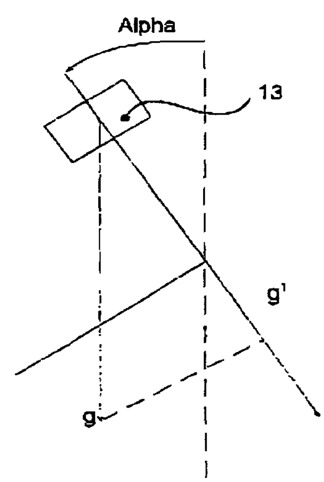


Figure 14B

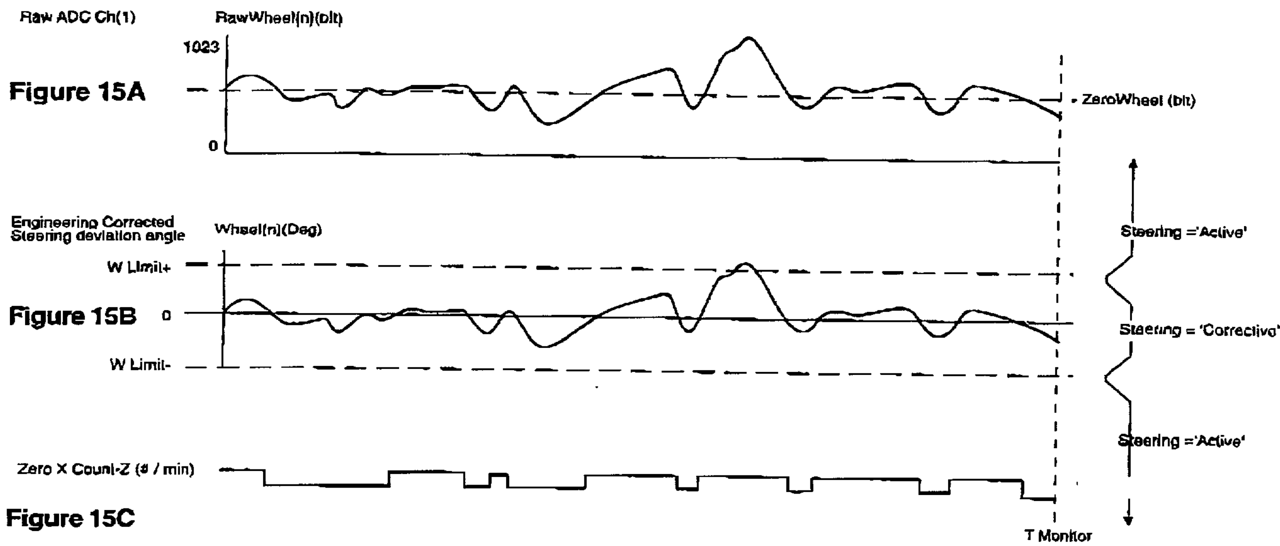


Table 3

RMS Steering Angle- $R(Deg) = \sqrt{\frac{\sum Wheel[n]^2}{n}}$

Table 4

Bound Check	
W Limit- < W < W Limit+	Steering Mode=Corrective
W < W Limit-	Steering Mode=Active
W > W Limit+	Steering Mode=Active

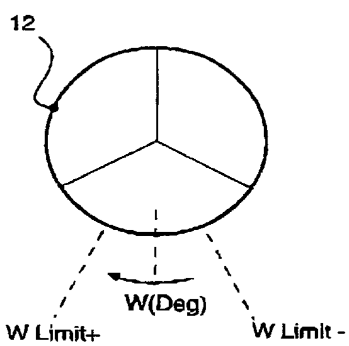


Figure 15D

09/341093

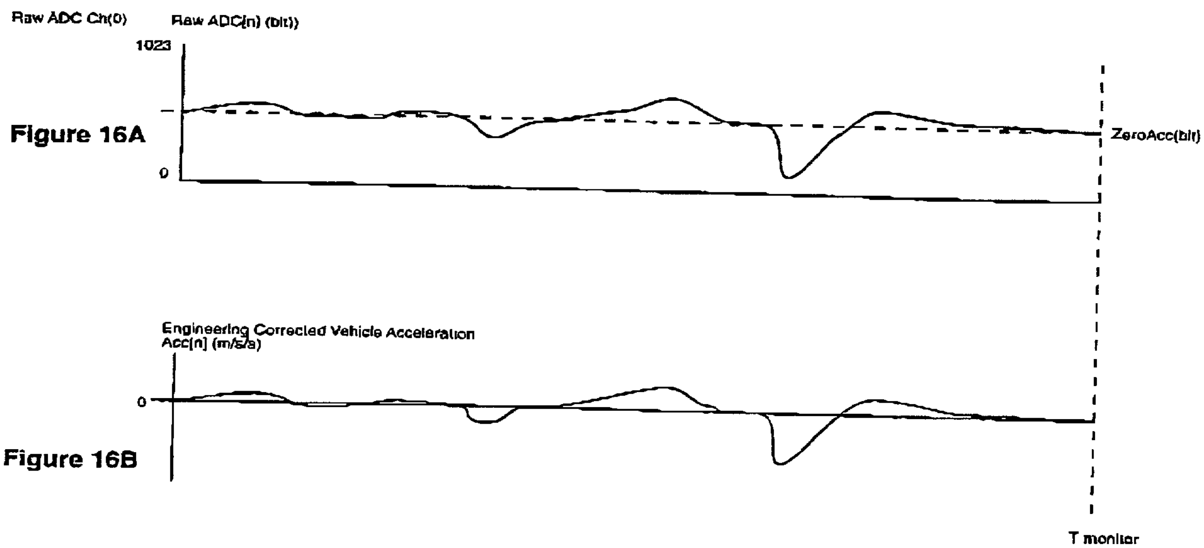


Figure 16A

Figure 16B

Table 5

$$\text{RMS Vehicle Acceleration-G(m/s/s)} = \sqrt{\frac{\sum Acc[n]^2}{n}}$$

09/341093

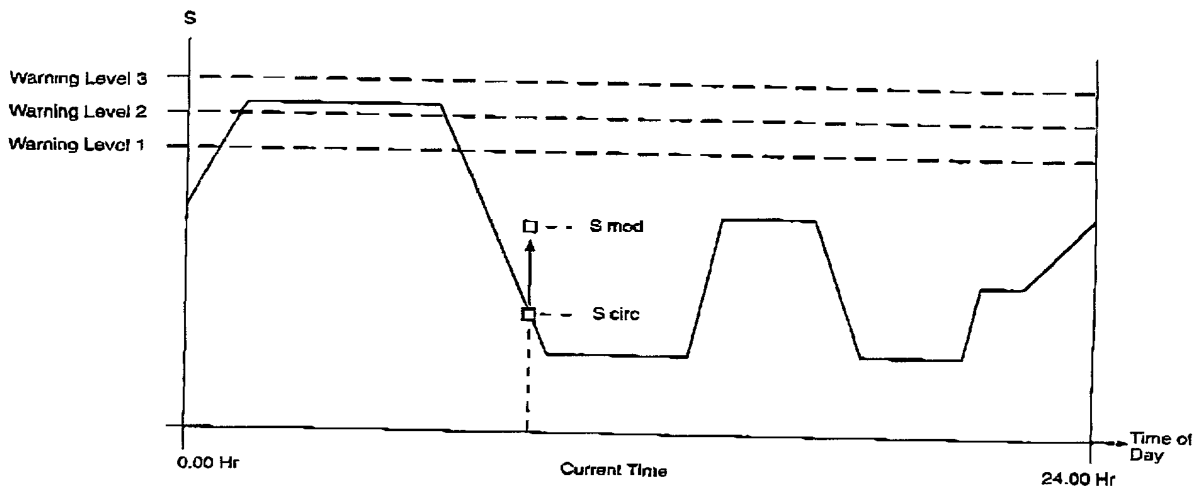


Figure 17

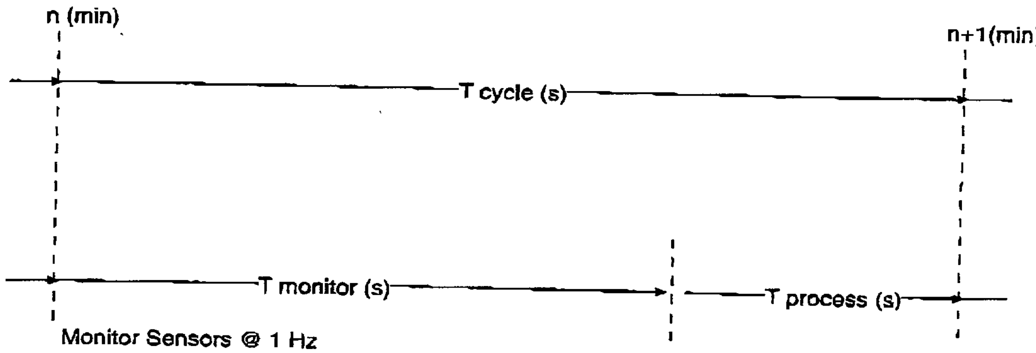


Table 6

T cycle = 60s T monitor = 50s T process = 10s	Calculate Parameters Test & Issue Warnings Update Screen Display Store Sensor Data > Disk Store Calculated Parameters > Disk

Figure 18

Figure 19

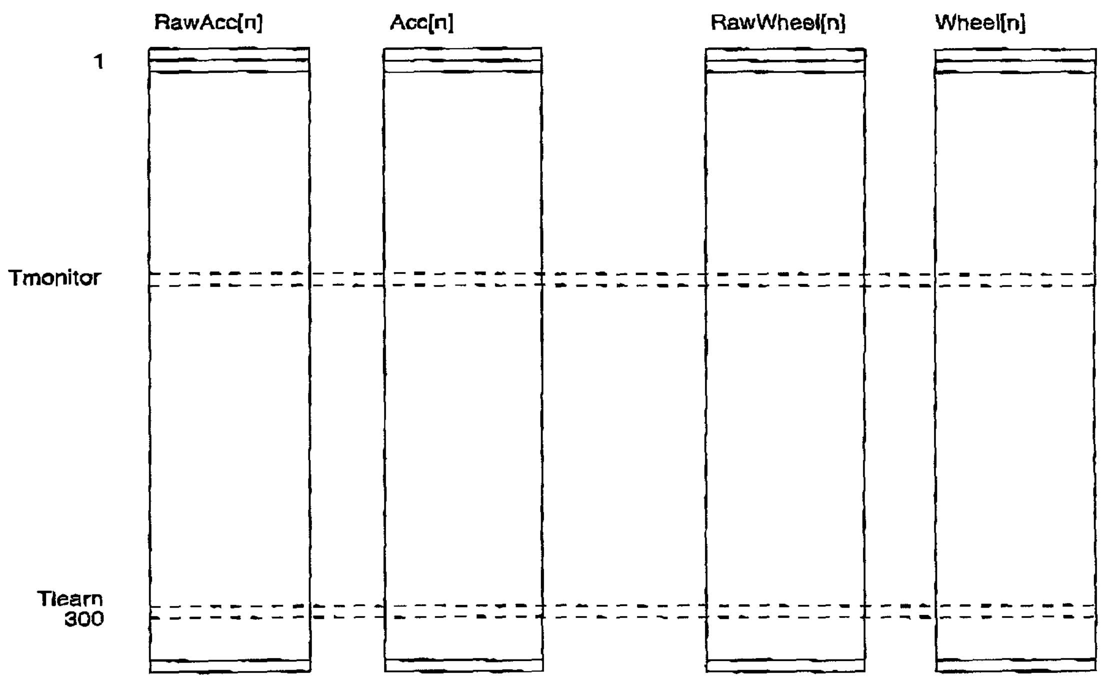


Table 7

Note:
Data storage @ 1Hz ZeroAcc=Average {RawAcc[n]} ZeroWheel=Average {RawWheel[n]} Ch(N)=Raw ADC Value (bit)

Table 8

Acc[n] = Kacc/1000 x (RawAcc[n]-ZeroAcc)x1/Cos(Alpha) (m/s/s) (mm/s/s/bit) (bit) (bit)
Wheel[n] = ArcSin [Kwheel/(1000x9.81) x (RawWheel[n]-ZeroWheel)x1/Cos(Alpha)] (Deg) (mm/s/s/bit) (bit) (bit)
I = Klight/1000 x (Ch(2)-ZeroLight) (KLx) (Lx/bit) (bit) (bit)
T = Ktemp/1000 x (Ch(3) - ZeroTemp) (DegC) (mDegC/bit) (bit) (bit)

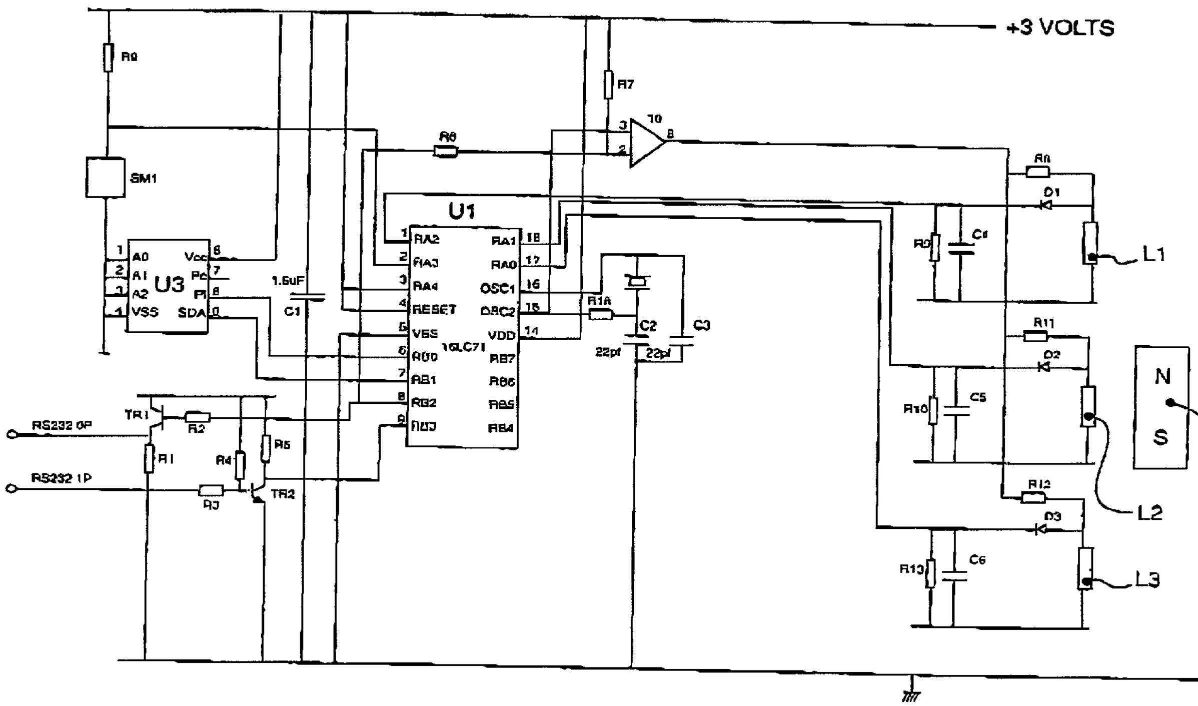

+3 VOLTS
R9
R7
R8
SM1
U1
U3
A0
A1
A2
VSS
Vcc
SDA
1.5uF
C1
RA2
RA3
RA4
RESET
VSS
RB0
RB1
RB2
RB3
RA1
RA0
OSC1
OSC2
VDD
RB7
RB6
RB5
RB4
16LC71
R1A
C2
C3
22pf
22pf
TR1
R2
RS232 OP
R1
R4
R5
RS232 IP
R3
TR2
D1
D2
D3
C4
C5
C6
R10
R11
R12
R13
L1
L2
L3
N
S
M

Figure 21

Table 1

Acc # 1-Vehicle Motion
Acc # 2-Wheel Angle
Light Sensor - Ambient
Temp Sensor - Ambient
Sounder
Mark Button

Table 2

W - Wheel Rotation Angle
X - Measured component of g in sensor axis (m/s/s)
K wheel - Sensor scaling factor (mm/s/s/bit)
g - Gravity 9.81 m/s/s
g - Gravity Vector Component in wheel Plane

Sin W = X / g

X = k wheel / 1000 x (Ch(1)-ZeroWheel) x 1/Cos(Alpha)

Sin W = k wheel / (1000 x g)x(Ch(1)-ZeroWheel)x(1/Cos(Alpha)

W + ArcSin [Kwheel /(1000 x g)x(Ch(1)-ZeroWheel)x 1/Cos(Alpha)]

Table 3

RMS Steering Angle- R(Deg) = $\sqrt{\frac{\sum \text{Wheel}[n]^2}{n}}$

Table 4

Bound Check

W Limit- < W < W Limit+	Steering Mode=Corrective
W < W Limit-	Steering Mode=Active
W > W Limit+	Steering Mode=Active

Table 5

$$\text{RMS Vehicle Acceleration-G(m/s/s)} = \sqrt{\frac{\sum Acc[n]^2}{n}}$$

Table 6

T cycle = 60s T monitor = 50s T process = 10s	Calculate Parameters Test & Issue Warnings Update Screen Display Store Sensor Data > Disk Store Calculated Parameters > Disk

Table 7

Note: Data storage @ 1Hz ZeroAcc=Average {RawAcc[n]} ZeroWheel=Average {RawWheel[n]} Ch(N)=Raw ADC Value (bit)

Table 8

Acc[n] = Kacc/1000 x (RawAcc[n]-ZeroAcc)x1/Cos(Alpha)

(m/s/s) (mm/s/s/bit) (bit) (bit)

Wheel[n] = ArcSin [Kwheel/(1000x9.81) x (RawWheel[n]-ZeroWheel)x1/Cos(Alpha)]

(Deg) (mm/s/s/bit) (bit) (bit)

I = Klight/1000 x (Ch(2)-ZeroLight)

(KLx) (Lx/bit) (bit) (bit)

T = Ktemp/1000 x (Ch(3) - ZeroTemp)

(DegC) (mDegC/bit) (bit) (bit)

Table 9

Engineering Scaling Factors	
K acc (mm/s/s/bit)	Acceleration Channel
K wheel (mm/s/s/bit)	Steering Channel
K light (Lx/bit)	Light Channel
K temp (mDegC/bit)	Temp Channel
ZeroLight (bit)	Intercept adjust - Light
ZeroTemp (bit)	Intercept adjust - Temp
Alpha (Deg)	Steering Wheel Inclination from Vertical
Hysterisis (Deg)	Hesterisis factor - Zero X analysis

Table 10

Sleep Propensity Algorithm - Definition	
S mod=S circ + S zerox + S rms + S light + S temp + S sleep + S road + S trip	
Elemental	Bound Limit
S mod	0<S mod <1
S circ	0<S circ <1
S zerox = (F zerox/100) (Z ref-Z)	0<S zerox
S rms = (F rms/100) (R-R ref)	0<S rms
S light = (F light/100) (I ref -I)	0<S light
S temp = (F temp/100) (T -T ref)	0<S temp
S sleep = (F sleep/100) (H ref - (HxQ))	0<S sleep
S road = (F road/100) (G ref -G)	0<S road
S trip = (F trip/100) x D	0<S trip

Table 11

Algorithm Elementals - S	
S mod (S)	Modified Sleep Propensity Factor-Range 0...1
S circ (S)	Current Circadian Sleep Propensity Value
S zerox (S)	Current Corrective Steering Reversal Rate Deficit
S rms (S)	Current RMS Corrective Steering Amplitude Surfit
S light (S)	Current Ambient Lighting Intensity Deficit
S temp (S)	Current Ambient Temperature Surfit
S sleep (S)	Prior Sleep Good Hours Deficit
S road (S)	Current Road Activity Deficit
S trip (S)	Accumulated Trip Duration

Table 12

Algorithm Weighting Factors - F	
Note : Factors are % S Unit per Parameter Unit	
F zerox (%S/#/min)	Corrective Steering Reversal Rate Deficit - % Factor
F rms (%S/Deg)	RMS Corrective Steering Amplitude Surfit - % Factor
F light (%S/kLx)	Average Ambient Lighting Intensity Deficit - % Factor
F temp (%S/DegC)	Average Ambient Temperature Surfit - % Factor
F sleep (%S/Hr)	Prior to Good Hours Sleep Deficit - % Factor
F road (%S/m/s/s)	Road Activity Deficit - % Factor
F trip (%S/Hr)	Accumulated Trip Duration - % Factor

Table 13

Algorithm Reference Offfsets - ref	
Z ref (#/min)	Corrective Steering Reversal Rate - Ref Offset Corresponds to 'Alert ' Driving Subject Dependent
R ref (Deg)	Corrective Steering RMS Amplitude - Ref Offset Corresponds to 'Alert ' Driving Subject Dependent
I ref (kLx)	Average Ambient Lighting Intensity - Ref Offset Corresponds to moderate daylight
T ref (DegC)	Average Ambient Temperature - Ref Offset Corresponds to moderate environment
H ref (Hr)	Prior to Good Hours Sleep - Ref Offset Corresponds to optimum value
G ref (m/s/s)	Road Activity - RMS Acceleration / Deceleration - Ref Offset

Table 14

Algorithm Dynamic Variables	
Z (#/min)	Current Corrective Steering Zero X Rate
R (Deg)	Current RMS Correvtive Steering Amplitude
I (kLx)	Current Ambient Lighting Intensity
T(DegC)	Current Ambient Temperature
G (m/s/s)	Current Road Activity - RMS Acceleration / Deceleration
D(Hr)	Accumulated Trip Duration
H(Hr)	Actual Hours of Prior Sleep
Q (#)	Prior Sleep Quality - Normalised Scale 0...1
Qx (#)	Prior Sleep Quality User Scale 1,2,3,4,5 Q=Qx/5

Table 15

Steering Mode & Steering Limit -W limit	
W limit (Deg)	Decision limit - Steering mode detection +W limit >W> -W limit >>> Corrective +W limit <W< -W limit >>> Active
Steering Mode	Steering mode decision ACTIVE, CORRECTIVE

Table 16

Alarm Levels & Alarm State	
Alarm Level 1 (s)	Alarm level threshold
Alarm Level 2 (s)	Alarm level threshold
Alarm Level 3 (s)	Alarm level threshold
Alarm Holdoff (min)	Initial alarm forced hold-off time - N minutes
Alarm State	Alarm status decision CLEAR, LEVEL1, LEVEL2, LEVEL3, HOLDOFF

Table 17

User Software Functions
Set Display Parameters
Enter New Values and <RET> or <RET> to bypass edit option.
Display History (min) — Graphic display history length - Last N minutes
FSD (S) — Graphic display full scale - S unit (0.. 1)

Table 18

Data Directiory Structure
[ALGO] *.ALG Algorithm Data Files - Internal Format
[USER]*.ALG User Data Files - Internal Format
[XALGO]*.CSV Algorithm Data Files - CSV Format
[XUSER]*.CSV User Data Files - CSV Format
[XDRIVE]*.CSV Drive Mode Data Files - CSV Format
[XLEARN]*.CSV Learn Mode Data Files - CSV Format

Table 19

File Structure - Program Internal Format	
Note : These files in program internal readable format	
Configuration File - SLEEPALT.CFG	
Save Set Values @ Program Shut Down	
Load Set Value @ Program Initialisation	
K acc	(mm/s/s/bit)
K wheel	(mm/s/s/bit)
K light	(Lx/bit)
K temp	(mDegC/bit)
K batt	(mV/bit)
ZeroLight	(bit)
ZeroTemp	(bit)
Hysterysis	(Deg)
Alpha	(Deg)
AlgorithmID	
UserID	
Circ[0] ... [23]	(S)
FSD	(0.. 1)
DisplayHist	(min)

09/341093

Table 20

Algorithm Data File [ALGO]*.ALG	
F zerox	(%S/#/min)
F rms	(%S/Deg)
F light	(%S/Klx)
F temp	(%S/DegC)
F sleep	(%S/Hr)
F road	(%S/m/s/s)
F trip	(%s/Hr)
Z ref	(#/min)
R ref	(Deg)
I ref	(KLx)
T ref	(DegC)
H ref	(Hr)
G ref	(m/s/s)
Alarm1	(s)
Alarm2	(s)
Alarm3	(s)
AlarmHoldoff (min)	
W limit (Deg)	

Table 21

User Data File [USER]*.USR
UserName
UserDoB
UserSex

Table 22

Data File Structure - Drive Mode Data File [XDRIVE]*.CSV
Note: These files in external readable format - CSV

DriveID
File Ceation Date
Start Time (Hr 0.. 23)
Start Time (min 0.. 59)
UserID
AlgorithmID

Alarm1 (s)
Alarm2 (s)
Alarm3 (s)
AlarmHoldOff (min)

W limit (Deg)

H (Hr)
Q (0.. 1)

F zerox (%S/#/min)
F rms (%S/Deg)
F light (%S/kLx)
F temp (%S/DegC)
F sleep (%S/Hr)
F road (%S/m/s/s)
F trip (%S/Hr)

Z (#/min)
R (Deg)
I (KLx)
T (DegC)
G (m/s/s)
D (Hr)

Z ref (#/min)
R ref (Deg)
I ref (Kix)
T ref (DegC)
H ref (Hr)
G ref (m/s/s)

S mod (S)
S circ (S)
S zerox (S)
S rms (S)
S temp (S)
S sleep (S)
S road (S)
S trip (S)

Minute Count (min) .... Repeat 1 .. N(min)
AlarmState
SteeringMode
Acceleration [1](m/s/s) Wheel[1](Deg)

DQC (Data Quality Code 0..255)

Acceleration [50] Wheel[50]

Table 23

Data File Structure - Learn Mode Data File [XLEARN]*.CSV

Note : These files in external readable format - CSV

Data File Structure - User Data File [XUSER]*.CSV

Note : These files in external readable format - CSV

UserID
File Creation Date

UserName
UserDoB
UserSex

Table 24

Data File Structure - Algorithm Data File [XALGO]*.CSV

Note : These files in external readable format - CSV

AlgorithmID

File Creation Date

F zerox (%S/#/min)

F rms (%S/Deg)

F light (%S/kLx)

F temp (%S/DegC)

F sleep (%S/Hr)

F road (%S/m/s/s)

F trip (%S/Hr)

Z ref	(#/min)
R ref	(Deg)
I ref	(KLx)
T ref	(DegC)
H ref	(Hr)
G ref	(m/s/s)

Alarm1 (s)

Alarm2 (s)

Alarm3 (s)

AlarmHoldOff (min)

W limit (Deg)

DC277.FP99.010

COMBINED DECLARATION AND POWER OF ATTORNEY

As a below named inventor, I hereby declare that

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

SLEEPINESS DETECTION FOR VEHICLE DRIVER OR MACHINE OPERATOR

the specification of which: *(check one)*

REGULAR OR DESIGN APPLICATION

[ ] is attached hereto.

[ ] was filed on July 2, 1999 as application Serial No. ______________ and was amended on ____________ (if applicable).

PCT FILED APPLICATION ENTERING NATIONAL STAGE

[X] was described and claimed in International application No. PCT/GB98/00015 filed on 05 January 1998 and as amended on ______________ (if any).

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, §1.56.

PRIORITY CLAIM

I hereby claim foreign priority benefits under 35 USC 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed.

PRIOR FOREIGN APPLICATION(S)

Country	Application Number	Date of Filing (day, month, year)	Priority Claimed
Great Britain	**9700090.5**	**04 January 1997**	**Yes**

(Complete this part only if this is a continuing application.)

I hereby claim the benefit under 35 USC 120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of 35 USC 112, I acknowledge the duty to disclose information which is material to patentability as defined in Title 37 Code of Federal Regulations §1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application:

(Application Serial No.) (Filing Date) (Status--patented, pending, abandoned)

POWER OF ATTORNEY

The undersigned hereby authorizes the U.S. attorney or agent named herein to accept and follow instructions from Tillbrook & Co. as to any action to be taken in the Patent and Trademark Office regarding this application without direct communication between the U.S. attorney or agent and the undersigned. In the event of a change in the persons from whom instructions may be taken, the U.S. attorney or agent named herein will be so notified by the undersigned.

7- As a named inventor, I hereby appoint the registered patent attorneys represented by Customer No. **000466** to prosecute this application and transact all business in the Patent and Trademark Office connected therewith, including: **Robert J. PATCH, Reg. No. 17,355, Andrew J. PATCH, Reg. No. 32,925, Robert F. HARGEST, Reg. No. 25,590, Benoît CASTEL, Reg. No. 35,041, Eric JENSEN, Reg. No. 37,855, Thomas W. PERKINS, Reg. No. 33,027, and Roland E. LONG, Jr., Reg. No. 41,949**, c/o YOUNG & THOMPSON, Second Floor, 745 South 23rd Street, Arlington, Virginia 22202.

Address all telephone calls to Young & Thompson at 703/521-2297. Telefax: 703/685-0573.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

1-00 Full name of sole or first inventor: **James Anthony HORNE**
(given name, family name)

Inventor's signature ____________ Date 21. Aug 99

Residence: **Leicestershire, England** GBZ. Citizenship: **British**

Post Office Address: **14 Paterson Drive**
Woodhouse Eaves
Loughborough
Leicestershire LE12 8RL England

2-00 Full name of second joint inventor, if any: **Louise Ann REYNER**
(given name, family name)

Inventor's signature ____________ Date 21/8/99.

Residence: **Leicestershire, England** GBZ. Citizenship: **British**

Post Office Address: **14 Paterson Drive**
Woodhouse Eaves
Loughborough
Leicestershire LE12 8RL England